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Tunguska Genetic Anomaly and Electrophonic Meteors – Part 2

Zurab K. Silagadze

4. Biological effects of ELF/VLF electromagnetic radiation

It is not excluded that one could use the magical herb mugwort (*Artemisia vulgaris*), the foremost sacred plant among Anglo-Saxon tribes, to resolve the enigma of the Tunguska genetic impact. It is said that mugwort can invoke prophetic dreams if used in a dream pillow (Cunningham 1985). Thus, a solution of the Tunguska riddle might be dreamed up in this way. But jokes aside, what is magical about mugwort is the suspected ability of *Artemisia vulgaris* to use the Earth's magnetic field for adaptation purposes. Mugwort is not the only plant with such an ability. For example, compass plant (*Silphium laciniatum*) uses the same adaptation strategy, which is even more pronounced in this case. Its basal leaves tend to align themselves with north and south. This allows them to avoid excessive heat of the midday sun and so minimize the moisture loss, while having maximum exposure to the morning and evening sun.

Some animals, including fish, amphibians, reptiles, birds and mammals, are also using geomagnetic field for orientation (Wiltschko & Wiltschko 1995). The sensory basis of magnetoreception is not completely clear yet. Two types of magnetoreception mechanisms are suspected in vertebrates. The evidence for a light-dependent, photoreceptor-based mechanism is reviewed by Deutschlander et al. (1999) along with some proposed biophysical models. It is supposed, for example, that a magnetic field can alter the population of excited states of photosensitive molecules, like rhodopsin, which might lead to chemical effects. But some experiments have shown that light is not necessary for magnetoreception (Wiltschko & Wiltschko 1995). Therefore, a mechanism for a direct sensing of the magnetic field should also exist. This mechanism is possibly based on chains of single-domain crystals of magnetite in a receptor cell (Walker et al. 2002). As the chain rotates in the magnetic field, it will open some mechanically gated ion channels in the cell membrane by pulling on the microtubule-like strands which connect the channels to the chain.

The above examples indicate that Earth-strength magnetic fields can affect biological systems. Moreover, this interaction provides evolutionary important tools for adaptation. Therefore, one can expect that the magnetic sense in biological systems is as perfect as any other known sensory systems and has evolved down to the thermal noise limit in sensitivity (Kirschvink et al. 2001).

Thus it is not surprising that various biological effects of the low frequency non-ionizing electromagnetic radiation have been found, although the underlying mechanisms responsible for these effects are still not completely understood (Marino & Becker 1977, Binhi & Savin 2001, Becker & Marino 1982, Binhi 2002). The potentially hazardous effects of the ELF (extremely low frequency) electromagnetic fields were especially scrutinized during recent decades because the power frequencies of most nations are in the ELF range. Let me mention some most impressive facts from the Marino and Becker's review (1977).

Even relatively brief exposures to high intensity ELF electric fields were shown to be fatal to mice, *Drosophilae* and bees. For example, being exposed to a field with intensity above 500 v/cm, bees sting each other to death. And the intensity of 30-500 v/cm at 50 Hz is sufficient to change metabolic rate and motor activity.

ELF electric field exposure affects the central nervous system as well. For example, a significant increase in hypothalamic activity was recorded from the microelectrodes implanted in anesthetized rats during a 1 h exposure period to the inhomogeneous electric field of 0.4 v/cm maximum at 640 Hz. Some in vitro studies indicate effects on the calcium release and biochemical function. For instance, 1.55 v/cm electric field at 60 Hz caused a complete loss of biochemical function in brain mitochondria after a 40 min exposure.

Exposure to the ELF electric or magnetic field produces a physiological stress response. For example, rats exhibited depressed body weights, decreased levels of brain choline acetyltransferase activity, and elevated levels of liver tryptophan pyrrolase after 30-40 days exposure to 0.005–1.0 v/cm electric field at 45 Hz.

It was found that an asymmetrically pulsed magnetic field repeating at 65 Hz with a peak

value of several gauss accelerates the healing of a bone fracture in dogs. Some studies indicated a slight enhancement of growth in plants near high-voltage transmission lines. The growth rate of beans was significantly (for about 40 %) affected by a 64 days exposure to 0.1 v/cm electric field at 45 Hz when the bean seeds were planted in soil. But no significant effect was observed when the soil was replaced with a nutrient solution.

Of course, possible genetic effects of VLF/ELF radiation are most interesting in the context of our goals. Some early work suggested that weak electric and magnetic fields produced genetic aberrations in *Drosophilae*; however these observations were not confirmed by subsequent experiments (Marino & Becker 1977). Epidemiological evidence of possible carcinogenic effects of electromagnetic field exposure is reviewed by Heath (1996) and Davydov et al. (2003). It seems that this is a subject of continuous controversy. Some studies suggest that exposure to power frequency electromagnetic fields may lead to increased risks of cancer, especially for leukemia and brain cancer. But other epidemiological studies did not reveal any increased risk. For example, eight of the eleven studies conducted in 1991–1995 found statistically significant elevation of risk for leukemia. And four of the eight investigations that studied brain cancer also found some increase in risk (Heath 1996). Nevertheless Heath considers the overall evidence as “weak, inconsistent, and inconclusive.”

For energetic reasons, VLF/ELF radiation of non-thermal intensity cannot damage DNA or other cellular macromolecules directly. On this basis, the possibility that such weak electromagnetic fields can induce any biological effects was denied for a long time (Binhi & Savin 2001), until a plethora of experimental evidence proved that “Nature’s imagination is richer than ours” (Dyson 1996). Let us mention one such recent experiment of Tokalov et al. (2003).

Cells have very effective emergency programs to cope with adverse environmental conditions. Remarkably, cellular stress response is rather uniform, irrespective of the stress factor nature. Some cellular functions that are not essential for survival, for example cell division, are temporarily suspended. Besides, special kind of genes, the so-called heat shock proteins (HSP), are activated. Their major function is the proper refolding of the damaged proteins. Heat shock proteins, notably the HSP70, were first discovered while investigating cellular responses to a heat shock, hence the name. Tokalov et al. (2003) studied effects of three different stressors on the induction of several heat shock proteins and on the cell division dynamics. The stress was produced by 200 keV X-ray irradiation, by exposure to a weak ELF electromagnetic field (50 Hz, 60 ± 0.2 μ*T*), and by a thermal shock (41°C for 30 min).

The pattern of induction of the most prominent members of the heat shock multigene family was found similar for all three stressors and HSP70 was the most strongly induced gene. But no effect on cell division was detected in the case of ELF electromagnetic field exposure, in contrast with other two stressors. Interestingly, when combined with the heat shock, ELF electromagnetic field shows a cell protective effect: the number of proliferating cells strongly increases in comparison with the case when only the heat shock stress is present. One might think that this protection property is related to the induction of HSP70 genes by the electromagnetic field which helps to cope with the thermal stress. But no protective effect was found when ELF electromagnetic field exposure was combined with ionizing X-ray irradiation. The reason of this difference is unknown, as are the molecular targets of the ELF electromagnetic field. It was suggested that electromagnetic fields can act directly on DNA by influencing electron transfer within the DNA double helix (Goodman & Blank 2002).

The fact that weak electromagnetic fields can induce the stress proteins indicates that cells sense electromagnetic fields as potentially hazardous (Goodman & Blank 2002). This is surprising enough, because the magnitude of an effective magnetic stimulus is very small. Electromagnetic fields can induce the synthesis of HSP70 at energy densities fourteen orders of magnitude lower than heat shock (Goodman & Blank 2002). Such an extra sensitivity to the magnetic field must have some good evolutionary grounds. Interesting thermo-protective effect of the ELF electromagnetic field exposure mentioned above, and the absence of any effects of weak electromagnetic fields on the cell proliferation, may indicate that cells are not really expecting any damage from the weak electromagnetic impulse, but instead they are using this impulse as some kind of early warning system to prepare for the really hazardous other stress factors which often follow the electromagnetic impulse. There is also another aspect of this problem: some recent findings in evolutionary biology suggest that heat shock proteins play an important role in evolution.

HSP90 guides the folding process of signal transduction proteins that play a key role in

developmental pathways. When HSP90 functions normally, a large amount of genetic variation, usually present in the genotype, is masked and does not reveal itself in the phenotype. However, under stress HSP90 is recruited to help chaperon a large number of other cellular proteins. Its normal role is impaired and it can no longer buffer variation. Therefore some mutations will become unmasked and individuals with abnormal phenotype will appear in the population. If a mutation proves to be beneficial in the new environmental conditions, the related traits will be preserved even after the HSP90 resumes its normal function. Therefore HSP90 acts as a capacitor of evolution. If environmental conditions are stable, the buffering role of HSP90 ensures the stability of the phenotype despite increased accumulation of hidden mutations in the genotype. When the environmental conditions suddenly change, as for example after an asteroid impact which is believed to have caused the dinosaur extinction 65 million years ago, this great potential for genetic variation is released in the phenotype and natural selection quickly finds new forms of life with greater fitness. The experiments of Rutherford and Lindquist (1998) with *Drosophilae* demonstrated this beautiful mechanism, which may constitute the molecular basis of evolution.

Further studies have shown that the HSP70 and HSP60 protein families also buffer phenotypic variation (Rutherford 2003). As was mentioned above, experiments demonstrated that ELF electromagnetic fields can induce various heat shock proteins and in particular HSP70. Therefore we can speculate that ecological and genetic consequences of the Tunguska event are possibly not related to mutations which happened during the event, but are manifestations of the latent mutations, already present in the Tunguska biota, which were unmasked due to the stress response. ELF/VLF radiation from the Tunguska bolide might act as a stressor thereby explaining why the effect is concentrated towards the trajectory projection.

Note that direct mutagenic effect of the TSB flight and explosion is not excluded either. Because the Tunguska bolide was an electrophonic bolide of an exceptional magnitude, very strong induced electric and magnetic fields are expected, which could induce significant Joule heating in biological tissues. One can even find witness accounts which can be interpreted as supporting this supposition, for example P. P. Kosolapov's report (Krinov 1949):

"In June 1908, at about 8 in the morning, I was in Vanavara settlement preparing myself for a hay harvest and I needed a nail. As I could not find it in the hut, I went out in the yard and began to drag out the nail by pliers from the window frame. Suddenly something seemed to burn my ears. Seizing them and thinking that the roof was on fire, I raised my head and asked S. B. Semenov who was sitting on the porch of his house: 'Did you see anything?' 'How couldn't it be seen, – he answered. – I felt as if I was embraced with heat.' After that I immediately went to the hut, but as I entered it and wanted to sit down on the floor to start work, a heavy blow followed, soil began to drop from the ceiling, the door of the Russian stove was thrown out on the bed which stood in front of the stove and one window glass was broken. After that there was a sound like a thunderclap which came from a northerly direction. When it became quiet again, I rushed out to the yard, but did not notice anything unusual."

Krinov notes that the eyewitness did not mention any light phenomena and explains this by the fact that he was near the south wall of the hut and thus was shielded from the north half of the sky, where the explosion took place. Krinov further speculates that the heat sensation was caused by the bolide glow as it flew overhead towards the explosion point. In our opinion a more realistic explanation is provided by the Joule heating due to an extraordinary strong electromagnetic pulse.

Many trees that survived in the epicentral area have characteristic damage as if originated from lightning strokes. One could expect that the explosion was accompanied by thousands of lightning strokes (Ol'khovatov 2003). It was proposed long ago that strong electric fields associated with thunderstorms could accelerate electrons to relativistic energies and lead to X-ray radiation, but all past attempts to register such radiation from lightning have produced inconclusive results. At last, however, recent rocket-triggered lightning experiments unambiguously demonstrated that lightning is accompanied by short intense bursts of ionizing radiation (Dwyer et al. 2003).

The detector used in these experiments (a NaI(Tl) scintillation counter) cannot distinguish between X-rays, gamma-rays and energetic electrons. So the actual composition of the radiation burst is unknown, but the fact that the radiation was not significantly attenuated by the 0.32 cm aluminum window on the top of the detector ensures that the particle energies were much more than 10 keV. The form of the observed signal indicates that

the signal was produced by multiple energetic particles. The bursts had typical durations of less than 100 microseconds and the total deposited energy was typically many tens of MeV per stroke. The energetic radiation seems to be associated with the dart leader phase of the lightning and precedes the return stroke by about 160 microseconds.

Similar observations were made earlier by Moore et al. (2001), who observed energetic radiation from natural lightning. In this case the radiation burst was associated with a much slower stepped leader phase and preceded the onset of the return stroke current by several milliseconds.

As we see at present, one has solid experimental evidence that lightning is a source of short bursts of ionizing radiation. Note that this experimental fact cannot be explained by the conventional theories of high-voltage breakdown at high pressures and therefore they need to be reconsidered (Krider 2003).

We do not know whether the TSB flight was also accompanied by ionizing radiation. This is not excluded as well because the strong electric fields associated with the alleged space charge separation could produce sufficiently energetic runaway electrons. Even if present, this radiation may be too attenuated before reaching the ground to produce significant biological effects. However, it seems very plausible that at least the Tunguska explosion itself was accompanied by intense bursts of ionizing radiation from lightning with possible biological consequences.

5. The riddle of the sands

We tried to argue in the previous sections that the genetic and ecological impact of the Tunguska event is possibly related to the powerful ELF/VLF electromagnetic radiation from the bolide and to the ionizing radiation due to lightning phenomena that accompanied the explosion. Note that ionizing radiation from the bolide and electromagnetic pulse as possible causes of genetic mutations were considered earlier by Andreev and Vasilyev (Trayner 1997) from a different point of view. A turbulent wave behind a large enough bolide can produce the required energetics of ELF/VLF radiation: for example by Keay-Bronshten mechanism. The TSB was very large indeed, with its estimated mass (prior to explosion) between 10^5 and 10^6 metric tons (Trayner 1997). The fact that no single milligram of this vast material was reliably identified in the epicenter region possibly tells against the asteroidal nature of the TSB (Bronshten 2000b). But the cometary theory may also fail to explain the low altitude of the explosion, as well as some specific features of the forest devastation at the epicenter. These features indicate that besides the main explosion there were a number of lower altitude (maybe even right above the surface) less powerful explosions (Vasilyev 1998). The most striking fact is that the impression of the ballistic wave on the forest seems to extend beyond the epicenter of the explosion, as if some part of the Tunguska object survived the huge explosion and continued its flight (Vasilyev 1998). Of course, it is a great enigma how an icy comet nucleus could lead to such strange effects.

Maybe the key to this riddle is buried in the Libyan Desert sands. In 1932 an incredibly clear, gem-like green-yellow glass chunks were discovered in the remote and inhospitable Libyan Desert in western Egypt.* Geologists dated the glass at 28.5 million years old and it is the purest natural silica glass ever found on Earth, with a silica content of 98 %. About 1400 tons of this strange material are scattered in a strewn field between sand dunes of the Great Sand Sea (Wright 1999).

The origin of the Libyan Desert Glass (LDG) is not completely clear. The LDG resembles chunks of layered tektite glass, the so-called Muong Nong type of tektite (Müehle 1998). Tektites are "probably the most frustrating stones ever found on Earth" (Faul 1966). The prevailing theory about their origin is that they are formed from the rocks melted in large meteorite impacts. But the secrets of glass making in such impacts are still unknown and some scientists even deny that such high quality glass (as one has for example in the LDG case) could ever originate from a powerful impact. The main argument against the terrestrial impact origin of tektites is the following (O'Keefe 1994). Tektites are unusually free from the volatiles, like water and CO_2, which are always present in terrestrial rocks. Glassmakers need several hours to remove bubbles from the melted material to produce the high quality glass in industrial glass-making process. But the impact is a very brief phenomenon, so there is not enough time to remove the volatiles.

O'Keefe himself preferred lunar volcanism as an alternative explanation for the origin of tektites (Cameron & Lowrey 1975). In this approach tektites are considered as "Teardrops from the Moon," in perfect agreement with ancient legends (Kadorienne 1997). This is a

* The so-called Libyan Desert covers not only the eastern part of Libya, but also the western part of Egypt, as well as the north-western part of Sudan.

very romantic theory of course, but it encounters even more severe difficulties (Taylor & Koeberl 1994). As a result, the impact theory reigns at present.

But the glassmaker objection should be answered, and usually one refers to a shock compression (Melosh 1998), the trick not used by glassmakers but expected in impact events. Due to a shock compression at 100 hPa, silicates almost instantaneously reach temperatures as high as 50000°C (Melosh 1998). Of course, nothing even remotely similar to such extreme conditions ever happens in industrial glass production. Therefore the comparison is not justified.

In the case of the Libyan Desert Glass, however, no impact crater has been found. Therefore, Wasson and Moore (1998) suggested that an atmospheric Tunguska-like explosion, but 10^4 times more powerful, was responsible for the LDG formation. This tremendous explosion heated 100 km $\times$ 100 km portion of the entire atmosphere to temperatures high enough to melt small desert sand grains, which were elevated by generated turbulence. As a result, a thin melted sheet of silicate was formed and a radiation background kept it hot enough for some time to flow and produce Muong Nong type tektites after solidification. Maybe multiple impacts produced by a fragmented comet, like Shoemaker-Levy-9 crash with Jupiter, are needed to ensure the appropriate scale of the event (Wasson 1995).

But the question about the high quality glass making reappears in this scenario, because now there are no extreme pressures associated with the impact cratering, and therefore no extreme compressive heating. Besides, evidence for a shock metamorphism was revealed in some sandstones from the LDG strewn field by microscopic analysis (Kleinmann et al. 2001). This points to an impact, not to an atmospheric explosion. But then, where is the crater? The situation is further involved by the recent strontium and neodymium isotopic study of these sandstones and of some LDG samples (Schaaf & Müller-Sohnius 2002). Isotopic evidence indicates a difference between the sandstones and LDG, so that the former cannot properly be regarded as possible source materials for the LDG (Schaaf & Müller-Sohnius 2002).

As we see, the Libyan Desert Glass and the Tunguska event suggest a very strange and peculiar type of impact. Maybe the required explanation should be also very peculiar – say the impact of a body made of mirror matter. Surely you would have a lot of glass after such an impact.

More seriously, the mirror matter idea is a completely sound and attractive scientific idea, which dates back to the Lee and Yang's (1956) seminal paper. This hypothetical form of matter is necessary to restore the symmetry between left and right. At the fundamental level the notions of left and right (left-handed and right-handed spinors) originate because the Lorentz group is locally identical to the $SU(2)\times SU(2)$ group (see, for example, Silagadze 2002). Therefore, one expects that the difference between these two factors of the Lorentz group, the difference between left and right, should be completely conventional and the Nature to be left-right symmetric. But ***P*** and ***CP*** discrete symmetries are broken by the weak interactions, so they cannot be used to represent the symmetry between left and right, if we want a symmetric universe. One needs a new discrete symmetry ***M***, instead of charge conjugation ***C***, so that ***MP*** remains unbroken and interchanges left and right.

Lee and Yang (1956) supposed that this new symmetry can be arranged if for any ordinary particle the existence of a corresponding "mirror" particle is postulated. These new mirror particles are hard to detect because they are immune to the ordinary gauge interactions. Instead, they have their own set of mirror gauge particles, which we are blind to. The only guaranteed common interaction is the gravity (for a review and references to the mirror matter idea see Foot 2001a, 2002, Silagadze 1997, 2001). Therefore big chunks of mirror matter could be detected by their gravitational influence. This means that in the Solar system we have not much mirror matter, if any. But *some* amount is certainly allowed. Even a planetary or stellar mass, a distant companion to the sun, is not excluded and represents a fascinating possibility (Foot & Silagadze 2001).

One can suppose that mirror matter constitutes a noticeable or even the dominant component of dark matter (Berezhiani et al. 2001, Foot & Volkas 2003). We know that there is a lot of dark matter in our galaxy and even in the solar neighborhood its density can reach roughly 15 % of the total mass density (Olling & Merrifield 2001). Therefore small asteroid sized mirror objects occasionally colliding with the Earth is a possibility which cannot be ruled out.

What would happen during such a collision depends on how mirror matter interacts with ordinary matter. If the predominant interaction is gravity, nothing interesting will happen, as the mirror asteroid would pass through the Earth unnoticed. But things would change if mirror and ordinary matter

interact via sizable photon–mirror photon mixing (Foot 2001b, Foot & Yoon 2002). In this case mirror charged particles acquire a small ordinary electric charge, they lose their immunity to the ordinary electromagnetic interactions and the mirror and ordinary nuclei will undergo Rutherford scattering, causing the drag force upon entry of a mirror space body into the atmosphere.

In a number of detailed studies (Foot 2001b, Foot & Yoon 2002, Foot & Mitra 2002) the entry of a mirror body into the Earth's atmosphere was analyzed. The outcome depends on several factors, such as the magnitude of the photon–mirror photon mixing, the size of the mirror space body, its chemical composition and initial velocity. As regards the Tunguska problem, the most interesting conclusion is that a large ($R \sim 40$ m) chunk of mirror ice, impacting the Earth with an initial velocity of about 12 km/s, will not be slowed down much by the drag force in the atmosphere, but it will melt at an altitude some 5 to 10 km. Once it melts, the atmospheric drag force increases dramatically, due to the body's expected dispersion, causing the body to release its kinetic energy into the atmosphere. Therefore an atmospheric explosion is expected.

If the TSB was indeed a mirror asteroid or comet, as suggested by Foot (2001b), the absence of the ordinary fragments is nicely explained. Of course, mirror fragments are still expected, if the body had significant nonvolatile component. Maybe these fragments are still buried at the impact site, but nobody bothers to dig them out.

Some other exotic meteoritic phenomena also appear less puzzling if one accepts that they were caused by mirror matter impactors (Foot & Yoon 2002). And not only on the Earth. Looking at the asteroid Eros and at its impact craters, Foot and Mitra (2002) came to an intriguing conclusion that the small mirror matter space bodies in the Solar system can actually outnumber the ordinary ones. The reasoning is as follows (Foot & Mitra 2002). When a mirror space body collides with an asteroid, it will release its kinetic energy at or below the asteroid's surface, depending on its size, velocity and the magnitude of the photon – mirror photon mixing. For small mirror bodies the energy is released too slowly and over too large a volume to expect any crater formation. Therefore a crater hiatus is expected at some critical crater size, if the craters are caused by mirror matter impactors. And this is exactly what is observed for Eros: a sharp decrease in rate was found for craters with diameter less than about 70 m.

Foot and Mitra (2002) were able to infer some estimation of the photon – mirror photon mixing magnitude from these observations. The result fits nicely in the range which is expected if anomalous meteoritic phenomena, and the Tunguska event in particular, were indeed caused by the mirror matter space bodies. There are some other interesting experimental implications of mirror matter which also involve the same range of the mixing parameter (for a review, see Foot 2003).

Eros reveals still another footprint of the mirror world. Puzzling flat-flaw crater "ponds" were unexpectedly discovered on its surface. The mirror impact theory provides a ready explanation (Foot & Mitra 2002): a large enough mirror matter space body, while releasing its energy underground, will melt surrounding rocks. If the photon–mirror photon parameter is negative, some extra heat is expected in addition to the kinetic energy. In this case mirror and ordinary atoms attract each other, so for the mirror matter chunk it is energetically favorable to be completely embedded within ordinary matter, releasing energy in the process (Foot & Yoon 2002).

Interestingly, an enigmatic flat-flaw crater can be found even on the Earth. It is the nearly circular 38 km wide Richât structure in Mauritania, at the western end of the Sahara desert. Nowadays this structure is no longer considered as an impact structure, despite its uniqueness in the region, the reported presence of coesite and its round "bull's eye" shape. The reason is that there are flat-lying strata at the center of the structure with no signs of the disrupted and contorted beds, as well as the lack of evidence for the shock-metamorphic effects, and the suspicion that the reported coesite is in fact misidentified barite (Everett et al., 1986). The Richât structure is believed to be a dome of endogenous origin sculpted by erosion. However, why it is nearly circular remains a mystery.

Maybe Eros ponds hint at a similar mirror matter explanation for this mysterious formation. Note that at 50 km to the west-southwest of the Richât structure one finds a similar but much smaller (of about 5 km in diameter) formation – the Semsiyat dome. If a "soft" impact of the main mirror body created the Richât structure, one can suppose that its large enough fragment might cause the Semsiyat dome.

One expects numerous lightning phenomena during a mirror impact event because the mirror space body would accumulate an ordinary electric charge while flying through the atmosphere. The charge builds up because the

ionized air molecules can be trapped within the mirror body, while the much more mobile electrons will escape (Foot & Mitra 2002). Interestingly, there were some speculations that the coesite-bearing quartzite breccias of the Richât structure were produced by lightning strokes (Master & Karfunkel 2001). As already mentioned above, there is evidence that the Tunguska event was accompanied by thousands of lightning strokes. More recently, one can mention January 14, 1993, anomalous low-altitude fireball event in Poland, a candidate for a mirror meteorite fall with an enormous electrical discharge at the impact site, which destroyed most of the electrical appliances in nearby houses (Foot & Yoon 2002).

There is something similar to the Libyan Desert Glass in south Australia, in the so-called Edeowie glass field (Haines et al. 2001). Unlike the LDG, this enigmatic fused crystal material is quite clast-rich and inhomogeneous. The enigma in this case consists in the fact that no impact crater has been found nearby, despite clear evidence that some rocks were melted *in situ*. Haines et al. (2001) concluded that lightning and impact-related phenomena are the only reasonable possibilities capable to produce the observed fusion. But maybe there is one more reasonable alternative: a large mirror body hitting the ground at a cosmic velocity (Foot & Mitra 2003), capable of providing both the impact and the spatially and temporally confined intense lightning phenomena.

6. Concluding remarks

We have considered some riddles in this article, such as the Tunguska genetic anomaly and electrophonic meteors, magnetoreception in biological systems and the molecular basis of evolution, Libyan Desert Glass and the Edeowie glass field, flat-flaw Eros craters and the Richât structure, parity violation and the hypothetical mirror matter, trying to argue that all these puzzles may be just different pieces of the same one big jigsaw puzzle. The picture that was assembled can hardly be considered as completely satisfactory, as in many cases we rely on hypotheses instead of firmly established scientific facts. Therefore, we cannot guarantee that the suggested picture is really the one created by the jigsaw puzzle author (Nature). Nevertheless this picture seems to be interesting enough to offer it for your attention.

As for the Tunguska genetic anomaly, we see the following explanation sufficiently reasonable. The Tunguska bolide was of electrophonic nature. That means its flight was accompanied by a powerful ELF/VLF electromagnetic radiation. This radiation acted as a stress factor on the local biota and triggered subtle mechanisms to release the hidden genetic variations into the phenotype. Some direct mutagenic factors that could be due to the ionizing radiation associated with lightning phenomena during the explosion cannot be ruled out either.

Interestingly, if the above explanation is correct, the Tunguska genetic anomaly represents in miniature the action of the molecular basis of evolution. On a much greater scale, the global catastrophic events, like the asteroid crash 65 million years ago which ended the dinosaur era, boost the evolution by the same mechanism. We are left to admire the Grand Design of Nature and try to survive its next evolutionary turn.

Finally, let us return to the outer space fears of sinful modern man. For a long time the ancient belief that the cosmos can influence our mundane affairs was considered by scientists as a mere superstition. “Modern astronomers generally scoff at such superstitious beliefs, so it is somewhat ironic that science has in the past few decades uncovered compelling evidence for celestial interference in terrestrial matters” (Jewitt 2000). It is now widely accepted that near-earth space objects larger than 1 km in diameter represent considerable hazard and in the past the Earth witnessed a number of withering impacts, which maybe shaped biological evolution. There are attempts to convince governments and society to fund ambitious projects to identify potentially threatening near-earth space objects and develop adequate defense systems (Jewitt 2000).

But the Tunguska event and some other mysterious events of probably impact origin indicate the enigmatic type of “soft impacts” – which do not leave any crater, nor impactor fragments, despite their tremendous magnitude. In this article we mentioned one possible explanation: that these impact events are caused by mirror space bodies. Of course, this explanation looks exotic, but in fact it is the only one falsifiable in the near future.

For the mirror matter explanation of anomalous impact events the crucial ingredient is the presence and magnitude of the photon – mirror photon mixing. And this can be experimentally tested! In fact the crucial experiment is already planned. This is the ETH-Moscow positronium experiment (Badertscher et al. 2003, Foot 2003). The photon-mirror photon mixing leads to the orthopositronium – mirror orthopositronium oscillations. As a result in some tiny fraction of events the orthopositronium will decay into

mirror photons and this will be detected as an event with missing energy. It is expected that the experiment will reach the needed sensitivity to prove or disprove the presence of the photon-mirror photon mixing of relevant magnitude (Badertscher et al. 2003, Foot 2003).

If the ETH-Moscow positronium experiment outcome turns out to be positive, it will mean bad news for mankind, except perhaps for the mirror matter theory proponents. The peculiarities of the Eros craters, if really caused by mirror impactors, indicate a significant population of small mirror bodies in the inner solar system. So the potential hazard for Earth is larger than estimated. More importantly, it is very hard, if not impossible, to detect an Earth-approaching mirror space body in time, to say nothing about averting its impact. Therefore we would be bound to face outer space hazards with eyes, so to say, wide shut.

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The "Weber Effect" and Anomalous Luminous Phenomena in the Earth Atmosphere in the Period of the Tunguska Event of 1908

Boris F. Bidiukov

In the monograph (Vasilyev et al. 1965, p. 63) its authors briefly mention a very extraordinary instrumental observation, seemingly connected with the Tunguska Event of 1908:

"Professor Weber of Kiel University… distinctly saw alterations of the magnetic declination of a magnetic needle, its oscillations occurring at regular intervals. These oscillations were observed: June 27-28 – from 6 PM till 1.30 AM; June 28-29 – from 6 PM till 1.30 AM; June 29-30 – from 8.30 PM till 1.30 AM. They had an amplitude of 2 angular minutes and the period of 3 minutes. Weber could not find for them any obvious causes. Unfortunately, the originals of Weber materials were destroyed during the Second World War… and therefore it is now difficult to judge about the true nature of these oscillations."

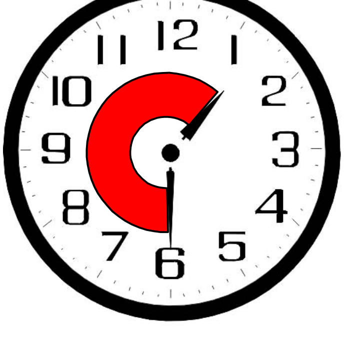
Weber's report was published in *Astronomische Nachrichten* journal, 1908, Vol. 178, No. 4262, p. 239, under the title "Von Herrn Prof. Dr. L. Weber, Kiel, Physikalisches Institut der Universität, 1908 Juli 11."

During the years following this publication researchers have, as a rule, restricted themselves to simply repeating these data, not trying to go deeper. The scarcity of information and the vagueness of the nature of this phenomenon seem to warrant such an approach, at least partly. At the same time, a closer examination of the data available, however scarce they may appear, can reveal some interesting regularities.

Having displayed the effect graphically in temporal coordinates (by Kiel time, which corresponds to middle European time), we have a clearer view:

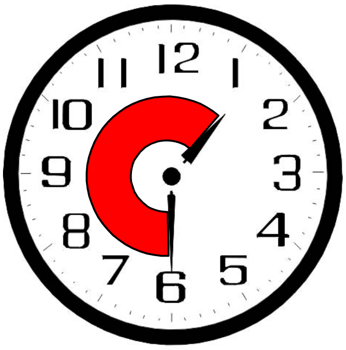
The night June 27 – June 28:

Start June 27, 1908, at 18:00; finish June 28, 1908, at 01:30. Duration of the needle oscillations: *7 hours 30 minutes.*



The night June 28 – June 29:

Start June 28, 1908, at 18:00; finish June 29, 1908, at 01:30. Duration of the needle oscillations: *7 hours 30 minutes.*



The night June 29 – June 30:

Start June 29, 1908, at 20:30; finish **June 30, 1908,** at 01:30. Duration of the needle oscillations: *5 hours 00 minutes.*



The dynamics of the effect during Weber's observations may be described as follows.

The moment of the beginning of the Tunguska event may be determined from the following considerations. In the work (Pasechnik 1986, p. 67) its author agrees with K. G. Ivanov (1965) that the regional geomagnetic disturbance, generated by the Tunguska explosion, started at 00 hours 20.2±0.2 minutes Universal Time. K. G. Ivanov, in his turn, points out in a recent work (Ivanov 2002, p. 857) that "…a time lag between the geomagnetic effect and seismic disturbance has been ascertained, the refined duration of this time lag being equal to 4.8±0.2 min." Therefore, judging from the seismic data, the Tunguska explosion started at 00 hours 15.4±0.2 minutes UT. Taking into consideration the time zone in Kiel differing by one hour from the Greenwich (Universal) time, for Kiel the explosion occurred at 01 hours 15.4 minutes, June 30, 1908.

In other words, the magnetic needle oscillations stopped in about 15 minutes *after* the Tunguska explosion.

And what's more, the explosion did *not* affect the oscillations, otherwise this would have been noted by Weber. It should also be emphasized that the explosion occurred, naturally enough, at the final stage of the motion of the Tunguska space body (TSB) through the atmosphere. Judging from eyewitness testimonies, the TSB flight duration was 5 minutes, according to (Zhuravlev, Zigel 1994, p. 130). Therefore, there must have passed between entering the atmosphere and the destruction (explosion) of the TSB some 10 minutes, or more, which shifts the beginning of the Tunguska *Event* to 01.00 by Kiel time (00.00 by Greenwich mean time). The duration of the explosion itself was much shorter than the TSB's time of flight.

Now, we should note that the "Weber effect" is a manifestation of some influence on the magnetosphere of the Earth that repeated regularly and with striking exactness during the three nights before the Tunguska Event.

On the first two nights the moments of the influence, beginnings and ends, coincided and the influence lasted in both cases 7 hours 30 minutes. The interval between the influences was **24 hours exactly**, that is one revolution of the Earth on its axis. On the third night the influence was "delayed" for 2 hours 30 minutes and lasted 5 hours. *The moments of the influence's end do nevertheless coincide on all the three nights*. It is intriguing that alterations "influence – no influence" are asymmetrical and not too regular (7.30 + 24.00 + 7.30 + 19.00 + 5.00), which makes any attempts of a natural ("not technogeneous") explanation of the influence that manifested itself in the "Weber effect" hardly plausible.

One should note that the regional geomagnetic storm, generated by the Tunguska explosion, started as indicated above at 01 hours 20.2 minutes by Kiel time. That is when the magnetic needle's oscillations, observed by Weber, lasted more than 4 hours without stopping (Bronshten 2002, p. 855). The geomagnetic storm ceased several hours after the oscillations stopped.

Thus, there is a strong impression that the Tunguska explosion, being a global cataclysm in itself, did not however affect in any noticeable way the source of the "Weber effect." At the same time, it appears doubtful that these two phenomena were fully independent. Conceivably there could exist some indirect linkage between them. For example, the source of the regular magnetic disturbances could for a long time remain in a circumterrestrial orbit, whereas its small fragment could be detected at the Podkamennaya Tunguska river.

In addition to the above considerations, we would like to compare the "Weber effect" with another – and better known – strange Tunguska-related effect: the so-called "anomalous luminous phenomena in the atmosphere."

"1. The anomalous luminous phenomena in the atmosphere of the Earth were mainly observed after the fall of the Tunguska meteorite. Their peak falls on the night June 30 – July 1, 1908, when they were recorded in more than 150 points of Europe and Asia; a sharp decline in their intensity occurred on July 1 and 2, but residual luminous phenomena did take place until the end of July, or even, according to some sources, until the end of August of 1908.

2. There is good reason to believe that subtle indications of light anomalies showed themselves even before the meteorite fall – beginning on June 22, or so, as some authors stated as far back as 1908. Before June 27 these sightings were isolated, but on June 27, 28, and 29 their number was rapidly increasing – in order to reach a sharp climax on the night from June 30 to July 1." (Vasilyev et al. 1967, p. 10)

It seems to have been a symptomatic coincidence that during the three days before the Tunguska Event the effect of light anomalies was increasing. But its culmination was "delayed" for about 24 hours, after which the intensity of the effect sharply decreased.

Let us cite one more source: "A great number of such observations were made by German observers. There is even an impression that the light anomalies had maximal intensity over the territory of Germany" (Vasilyev et al. 1965, p. 28). As pointed out in the work (Romeyko 2000, p. 61), "the maximal value ΔE = 1000–20000 (of the level of illuminance) was observed in Germany and Belgium."

In other words, both the "Weber effect" and light anomalies do seem to "concentrate" in the territory of Germany, which is at least strange. This co-occurrence can hardly be explained away as pure accident. What is more, when trying to explain the "Weber effect" by an influence of some industrial interference (say, a closely located source of electromagnetic waves that manifested only from June 27 till June 30) one is obviously inclined to forget about the light anomalies that appeared the same days. These covered a very large territory and definitely could not be associated with any terrestrial technological activities.

In conclusion, the author wishes to express his sincere gratitude to his colleagues – V. I. Zyukov, B. R. German, and V. K. Zhurav-

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Radioactivity at Tunguska

Preliminary notes to the program of further investigations of radioactive fallout in the area of the Tunguska explosion of 1908

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From the viewpoint of traditional meteoritics, there are a number of anomalous features of the Tunguska catastrophe of 1908. The magnitude of the explosion, its overground character, the lack of an astrobleme and any material remnants of the Tunguska space body (TSB) all provide a reason to interpret this unique event in a non-traditional way. Mention may be made, first of all, of the following four unconventional hypotheses which have been advanced since 1946:

1. TSB as an extraterrestrial spacecraft (Kazantsev 1946 [1]).
2. TSB as a piece of antimatter (La Paz 1948 [2]).
3. TSB as a "microscopic black hole" (Jackson and Ryan 1973 [3]).
4. TSB as a "solar plasmoid" (Dmitriev and Zhuravlev 1984 [4]).

The former two versions imply the nuclear nature of the Tunguska explosion – that it was accompanied by nuclear reaction of fission, fusion, or (for hypothesis 2 especially) matter annihilation.

To verify these suppositions, in the area of the Tunguska catastrophe, research was carried out from 1959 to find traces of radioactivity by direct and indirect methods, both in the epicentral region and along the supposed dispersion train of the TSB substance. These works included the following investigations:

1. Gamma and beta-radiometry of soil, peat and vegetation (in the years 1959, 1960, 1965, 1970, 1972–1974, and 1990).
2. Obtaining gamma-spectra of the vegetation and tree rings.
3. Determination of content of the radioactive isotope of potassium – ^{40}K (1960).
4. Determination of content of uranium in the rock (1960).
5. Determination of the level of radioactivity of the soil at spots shielded from the radioactive fallout after 1945.
6. Determination of the isotopic contents in the gases that were absorbed in rock (1975).
7. Investigations of the termoluminiscent properties of rocks (1966) and soils (1977-1991).
8. Examination of ^{14}C in trees and peat (1961–1990).

The main results of these investigations may be formulated as follows:

1. Generally, radioactivity of the soils in the area of the Tunguska explosion is within the range of fluctuations of the natural background.
2. At the same time, its magnitude is 1.5–1.7 times higher at the epicenter than at the pe-

riphery of the region. The center of this local increase is located at the foot of Farrington mountain (in the epicentral zone).

3. Local fluctuations of the radioactivity of soils are stable. In particular, they did not change essentially from 1959 till 1970. Therefore, these fluctuations are not due to short-lived radioactive isotopes.

4. Beta-radioactivity of the vegetation and trees at the epicenter of the Tunguska explosion is 1.5–2 times higher than at the periphery of the region and in the vicinity of Moscow. These variations are not due to variations of the content of ^{40}K.

5. Beta-radioactivity of tree rings has been growing exponentially, beginning from 1945, which can be explained by the increasing concentration of ^{137}Cs and ^{90}Sr due to nuclear tests at this period. Sometimes the ring of 1908 gives another peak of radioactivity, as well as of the level of concentration of ^{137}Cs. However, it occurs only in those trees that were damaged in 1908 and have therefore cracks and hollows through which present-day fallouts can get into the trees.

6. There exist in the region, apart from the residual radioactivity connected with the atmospheric nuclear tests that were actively performed in the USSR and USA in the period of 1958–1963, also traces of more recent Chinese nuclear tests and traces of the Chernobyl disaster.

7. Concentration of ^{14}C in tree rings incorporating the ring of 1908 has increased. However, a similar increase takes place in some other regions of the globe (California, India, the north of the Tomsk Region in Russia). The most plausible explanation of this effect would be a superposition of two cycles of Solar activity (11-year and 80-year ones), falling on the years 1908–1909.

8. The ^{14}C effect has a "patchy" character. In some trees it can be found, whereas in other ones it is definitely absent.

9. Beta-radioactivity of peat has been increasing exponentially, beginning from 1945, also due to the growing concentration of ^{137}Cs. At the same time, there was discovered at one spot in the region a second peak of radioactivity in the peat layer incorporating the year 1908. The origin of this peak has remained unclear.

10. Data about the radioactivity in open test pits attest that it is connected mainly with the upper layer of the soil (0–5 cm) and owes its origin to the contemporary fallouts after nuclear tests.

11. Studying radioactivity of soils in open test pits at the places that are shielded from contemporary nuclear fallouts shows the lack of artificial radionuclides in the upper layer of the soil. One should, however, take into consideration that these samples have been taken from under the floors of the hunter cabins, built before 1945, and when such cabins were built the upper layer of the soil was usually removed.

12. The isotopic content of argon in gases in local rocks has not been modified. This testifies against the supposition about a powerful stream of radiation at the moment of the Tunguska explosion, as well as against any reactions of annihilation between matter and antimatter during this explosion.

13. Thermoluminescent properties of rocks and soils in the epicentral zone of the area have been reduced due to annealing (caused by radiation burn and fire). Even if there was an effect of increased thermoluminescence due to ionizing radiation, it had therefore been obliterated. In this connection it merits notice that in the north-eastern part of the epicentral zone, where the intensity of the radiation burn was, for reasons not well understood, rather low (the so-called "blind spot" of the burn) the thermoluminescent properties of rocks and soils have sharply increased. There are strong grounds for believing that the high values of thermoluminescence at the "blind spot" may be interpreted as evidence of the action of ionizing radiation on the crystal lattice of minerals at the moment of the explosion. Outside the confines of the zone of the radiation burn the levels of thermoluminescence are within their background values. The area of the zone of the radiation burn is about 400 sq. km.

14. The content of ^{14}C in the "catastrophic" layer of peat has decreased – probably at the expense of the "dilution" of ^{14}C by the "dead" isotope ^{13}C.

Results of expert assessments

Academician Boris V. Kurchatov, the father of Soviet radiochemistry, and his close associate Dr. Vladimir N. Mekhedov were engaged in studies of radioactivity in the area of the Tunguska explosion in the 1960s. In private correspondence B. V. Kurchatov stated that:

1. The pattern of peat radioactivity in the area of the Tunguska catastrophe is not easily explainable.

2. To perform deeper investigations, with more accurate measurements of near-background values, special equipment is needed. Letters by B. V. Kurchatov are kept in the archives of the Independent Interdisciplinary Tunguska Expedition.

V. N. Mekhedov summarized results of his investigations of the peat radioactivity in a

booklet, published in Obninsk in 1967 [5]. His main conclusions are as follows:

1. The radiation effect does exist.
2. The main component of the radiation is X-rays.
3. The source of this radiation is, most likely, radioactive chlorine.
4. To make truly accurate measurements, 4π-counters are necessary, which could measure the intensity of radioactivity in the X-ray band.

Alas, the premature deaths of B. V. Kurchatov and V. N. Mekhedov have stopped these works before their completion.

Preliminary conclusion

The question of radioactivity in the area of the Tunguska explosion remains open. At the same time, there are some peculiarities possibly connected with the unusual event of the summer of 1908. Equipment used at nuclear test sites cannot be effectively utilized for measuring near-background levels of radioactivity. It is definitely necessary to obtain spectra of radioactivity in the X-ray band, using 4π-counters.

The main task for the future

It is necessary to obtain an unequivocal answer to the question, whether or not there are at the area of the Tunguska explosion any radioactive isotopes that could get there in 1908.

The investigative techniques

Obtaining high resolution spectra of radiation of soil and peat – first of all, in "suspicious zones": (a) at the epicenter; (b) in the zone of the "blind spot" of the burn and the maximal levels of thermoluminescence; (c) in peat bogs near Vanavara, where exists a second peak of radioactivity in the depth of the peat deposit; (d) at the places that are shielded from the post-1945 radioactive fallouts.

Time allowed for the work: 3 to 5 years.

Additional arguments in favor of fulfilling this work are:

1. The definite similarity – if not identity – of the regional geomagnetic storm that began several minutes after the Tunguska explosion with geomagnetic disturbances following nuclear explosions in the atmosphere.
2. The existence at the epicenter of the Tunguska explosion of a zone of a sharply increased frequency of mutations in plants.

The final solution of the question whether or not there are in this region any traces of artificial radioactivity that date back to 1908 would offer a clearer view of the physical picture of the Tunguska explosion and the nature of the Tunguska space body.

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Questioning Witnesses in 1926 about the Tunguska Catastrophe

Innokentiy M. Suslov

Note by the Editor: *This paper was written by the well-known Russian geographer, ethnographer and public figure I. M. Suslov (1893–1965), who spent many years working in Evenkiya (the territory of the Evenks or Tungus). Suslov's organizing efforts have contributed a lot to the success of the first expeditions of L. A. Kulik to the epicenter of the Tunguska explosion. In 1926, he questioned the people who had seen the Tunguska event with their own eyes. Part of the material collected appeared in his article published in Mirovedeniye journal (1927, No. 1). Much later, shortly before his death, I. M. Suslov informed the Siberian Commission on Meteorites and Cosmic Dust that he had some additional material which he would like to make public. After he gave them a manuscript, it was, with some abbreviations, published in the collection of papers The Problem of the Tunguska Meteor-*

ite (Tomsk: Tomsk University Publishing House, 1967, pp. 21-30). The paper by I. M. Suslov contains first-hand accounts of those people who happened to become eye-witnesses of one of the most imposing events of the 20th century. Here we publish the first complete English translation of the paper, trusting that it will be of considerable use and value to those RB readers who take an interest in the problem of the Tunguska meteorite.

The very first reports about the Tunguska catastrophe of June 30, 1908, came to my attention some two or three months after the event. Those were the years of my gymnasial youth in the town of Yenisseysk. The catastrophe was witnessed by workers, gold-diggers, and tenants of local gold-fields, who worked in taiga, some 250–300 km to the north-east from Yenisseysk, as well as by peasants and fishermen on the Angara river. With the help of R. A. Frenkel, a teacher at our gymnasium, I tried to determine an approximate geographical location of the center of the meteorite fall (or explosion) and to find out how it would be possible to get there.

In 1912 I finished at the gymnasium and left Yenisseysk. My examination of the witnesses' reports stopped. But in the years 1924–1925 I resumed this work in villages on the Angara and partly at trading stations on the Podkamennaya Tunguska river. Being the Chairman of the Krasnoyarsk Committee for Assistance to Northern Peoples, I had to visit these places to prepare the election of the first agencies of Soviet power in Evenkiya – the Tribal Councils and Tribal Courts. It was for the organization and preparation of *Munniak* (a meeting of the electorate) that I went in March of 1926 to the Chunia river.

Not far from the *faktoriya* (trading station) of Vanavara I saw the *chum* [a tent of skin or bark] of Ilya Potapovich (Luchetkan), an Evenk, in whose family lived also Akulina, the widow of his brother Ivan. In June 1908 their *chum* stood at the mouth of the Dilyushmo river near the place of its confluence into the Khushma river. Akulina recounted about this event in following words:

– "We were three in our *chum* – I with my husband Ivan, and the old man named Vassiliy, son of Okhchen. Suddenly, somebody pushed our *chum* violently. I was frightened, gave a cry, woke Ivan and we began to get out of our sleeping-bag. Now we saw Vassiliy getting out as well. Hardly had I and Ivan got out and stood up when somebody pushed violently our *chum* once again and we fell to the ground. Old Vassiliy dropped on us as well, as if somebody had flung him. There was a noise all around us, somebody thundered and banged at the *elliun* (the suede cover of the *chum*). Suddenly it became very light, a bright sun shone at us, a strong wind blew at us. Then it was as if somebody was shooting, like the ice breaks in the winter on the Katanga river, and immediately after that the *Uchir* dancer swooped down, seized the *elliun*, turned it, twirled it, and carried it off – somewhere. Only the *diukcha* (the *chum's* framework, consisting of 30 poles) has remained at its place. I was frightened to death and became *bucho* (lost consciousness), but now see – the *uchir* (whirlwind) is dancing. I gave a cry and came back to life (regained consciousness).

"The *uchir* hurled on me the *diukcha* and hurt my leg with a pole. Now I got out from under the poles and began to cry: the small box with plates and dishes is thrown away from the *chum* and is lying at a distance, it is open and many cups have been broken. I am looking at our forest and cannot see it. Many a tree stand without branches, without leaves. Plenty of trees lie on the ground. Dry trunks, branches, deer moss are burning on the ground. Now I see some clothes burning, I came and see – this is our blanket from hare-skin and our fur bag, in which I and Ivan slept.

"I went to look for Ivan and the old man. Now I see something hanging on a twig of a naked larch. I approached, stretched a stick and took it down. This was our peltry that had been suspended on the *chum's* poles. Fox pelts was scorched, ermine became yellowish, dirty and sooty. Many squirrel's skins have broken into wrinkles and got too dry.

"Now I took our peltry and went, crying, to search for my men. And the dry wood was still burning on the ground, deer moss was burning, the air was filled with smoke.

"Suddenly I hear somebody moaning softly. I went to the voice and saw Ivan. He was lying on the ground between the branches of a big tree. His arm has broken over a log, the bone showed through the shirt and protruded on the outside, with blood dried on it. Now I fell down and became *bucho* again. But soon I returned to life again. Ivan has 'awaken' and began to moan louder and to cry.

"The *uchir* threw Ivan near. If ten *chums* are placed in sequence then he fell down beside the last chum, quite near to the place where I took off the peltry from a twig.*

"Well, Ivan put his healthy arm round my neck. I helped him to stand up and we moved

* Diameter of a *chum* is some four meters; therefore, Ivan was thrown away for about 40 meters. – *The Author.*

towards our *chum* at the Dilyushma, where there were in a *labaz* (storehouse) two elk skins, a bag of flour, and fishing nets. The *chum* stood at a beach of the Dilyushma river, the *labaz* was not far from it, to the sunset. Suddenly we seem to hear somebody give a cry. Now we happened to see our Vassiliy. He got under the roots of a fallen larch and hid there. I got tired, handed Ivan over to the old man, and got to carry the burned peltry alone.

"Now walking became still more difficult: there were so many fallen trees around. Suddenly we saw on the ground logs and elk skins under them. The hair on the skins had burnt, the skins themselves broken into wrinkles and also burnt. Instead of the fishing nets, we saw a heap of small stones – sinkers. The nets made from the horsehair had completely burnt. The logs had also burnt out, turning into firebrands. Instead of the bag of flour – just a black stone. I have thrust it with a stick and the stone-coal broke. Inside it I found some flour and rolled the flour up in Vassiliy's shirt. That's how our *labaz* has perished. After a short rest, we went to look for our *chum*.

"And now here it is, the place where our *chum* had stood. The poles lie on the ground, with a large fallen larch on them, the latter having been much burnt. I have cut it with my axe and dragged it to one side. Under the larch we have found our copper cauldron in which there was a lot of yesterday's meat.

"A light summer night has fallen. The fire diminished. It became colder. We decided to go to the Katanga. When we reached the Chamba, we were already very weak. And we saw around us a miracle, a terrible miracle. The forest was not our forest. I have never seen such a forest in my life. It was so unfamiliar. We had here a dense forest, a dark forest, an old forest. And now there was in many places no forest at all. On the mountains all the trees were lying down and it was light; one could see far away. And it was impossible to go under the mountains, through the bogs: some trees were standing there, others were down, still others were bent, and some trees had fallen one upon another. Many trees were burnt, dry trunks and moss were still burning and smoking. Having come to the Katanga we met with Luchetkan."

Akulina's story is presented here in abbreviated form: I have omitted some details having no direct relation to the Tunguska catastrophe.

From the *faktoriya* of Vanavara I left for Strelka-Chunia. There I met with the brothers Chuchancha and Chekaren of the Shanyagir kin.

At the moment of the catastrophe of 1908, their *chum* stood near the *chum* of their father in the middle reaches of the Avarkitta river. Both brothers proved to be interesting and intelligent interlocutors and narrators. They spoke Russian fairly well in the Angara-Tungus dialect. Chuchancha has essentially repeated Akulina's description of events, but I have asked him to recall how many thunder blows – "*agdyllian*" – occurred and how strong they were. In Chuchancha's opinion, he counted five blows.

"Our *chum* stood then on the bank of the Avarkitta. Before sunrise I and Chekaren came from the Dilyushma river where we stayed with Ivan and Akulina. We had fallen fast asleep. Suddenly both of us instantly awoke. Somebody gave us a push. Then we heard a whistle and felt a strong wind. Chekaren even exclaimed: 'Do you hear? There are so many goldeneyes or mergansers flying.' We were still inside our *chum* and could not see what was happening in the forest. Suddenly I got another push from somebody – so strong that I knocked my head against the *chum's* pole and then fell onto the hot coals in the hearth. I got frightened. Chekaren had also got frightened and snatched at the pole. We began to call our father, mother and third brother, but nobody replied. A loud noise was heard from the outside of the *chum*. We realized that trees were falling. Chekaren and me, we got out from our sleeping bags and were going to go out of the *chum*, but suddenly there was a very great clap of thunder. This was a first blow. The earth trembled, a strong wind hit our *chum* and threw it down. The *elliun* rode up and I saw something terrible: trees were falling down, their pine-needles burning. Dead branches and deer moss on the ground were burning as well. Smoke is all around. The eyes ache, it's hot, very hot, one could burn out.

"Suddenly there appeared above a mountain, where the trees had already fallen down, a bright light like a second sun. The Russians would have said: it has unexpectedly flashed. It was like what the Russians call '*molniya*' (lightning). At this very moment a strong *agdyllian*, thunder, crashed. This was a second blow. The morning was sunny, no clouds, the sun shone as always, and now a second sun!

"With an effort I and Chekaren crawled out from under the *chum* poles and *elliun*. After that we saw a flash appear again and a thunder crash heard again overhead, although in another place. This was a third blow. Then there was a new gust of wind that knocked us

down and we knocked ourselves against a leveled tree.

"Now, we were looking at falling trees, we saw their tops break, we watched the forest fire. Suddenly Chekaren cried out: 'Look up!' and stretched his hand upward. I looked in this direction and saw a new lightning, with an *agdyllian*. But its sound was not so loud as before. This fourth blow was like a usual thunder.

"Now I can remember there was a fifth blow, but rather weak and far away from us."

"But at which side did you hear this last, fifth thunder?" I asked the brothers.

"Well, it was where the sun is sleeping in the winter, where the Taymura river is," replied Chuchancha.

I attempted to make a quantitative estimate of the lapse of time between the first and the second blows. It could be done only through comparison with a time interval well-understood by the Evenk hunters.

So, I decided to use the effect of echo. Several days earlier, I was making a route survey of the environs of the Strelka Chunya river. One of my routes went along the Northern Chunku-kan river, where there was a rock not far from the Strelka. I brought with me the brothers Shaniagir to the cliff of the Syrka rock, from which one could see both the place of confluence of the two rivers Chunku-kan into one river, and the rock. The distance between the rocks is 1020 meters.

"Look there," I told the brothers. "Stepan Ivanovich, please shoot from both barrels towards that rock at Chunku-kan. First we will hear the report, which will be the first clap of thunder, and then we will hear its echo, which will be the second clap of thunder. Please note how long will be the interval between the shots and the echo."

We went down to the water. Chuchancha and Chekaren shot several times, in turns, and I noted the moments of shooting. Naturally enough, the echo was heard 6 seconds after each shot. Both brothers stated that just the same time interval was between the first and the second claps of thunder.

Before the closing of *Munniak* I appealed to all its participants, asking them to verify the facts reported by Akulina, Vassiliy the old man, and the brothers Chuchancha and Chekaren, hoping also to obtain additional data. There were some difficulties in this attempt. I knew that the Evenks attributed the catastrophe of 1908 to shaman Magankana's revenge, carried out by a flock of iron birds (*agdy*). Trying to refute this idea was utterly useless, the more so as the Evenks believed the old man Vassiliy of the Shaniagir kin (who also attended the *Munniak*) "had seen these birds with his own eyes" and "heard how they roared."

Therefore, I had to find a roundabout way to get the people to talk about the subjects that were forbidden by their religious "taboos." I addressed the delegates asking them to tell in some detail who of them had suffered through the catastrophe; where the zone of tree leveling began and where it ended, as well as whether somebody had seen holes in the ground that had appeared after the catastrophe.

An excited conversation started among the Evenks who were sitting in the glade. There even arose a heated debate. Then the old man named Ulkigo, a son of Lurbuman of the Shaniagir kin, began to speak. It was believed Ulkigo was 80 years old.

"The *chum* of my father Lurbuman stood on the bank of the Chamba river, not far from its mouth. There lived in this *chum* my father, I with my wife, and our four children. One day, early in the morning, dogs suddenly started howling and the children began to cry. My wife, I and the old man awoke and saw a miracle. We began to listen and heard somebody begin to knock on the ground below us and swing the *chum*. I jumped out from the sleeping-bag and started to dress myself, but now somebody pushed the ground violently. I fell and shouted, the children shouted too and jumped out from their sleeping-bags. Shortly before that, somebody was strongly shooting from guns. Well, the old Lurbuman said a rock had fallen near the Churgim stream. Suddenly again – as if somebody knocked at the ground very strongly in our *chum* – a copper kettle fell down and somebody made the Angara thunder.* I dressed up soon afterwards and ran out from the *chum*. The morning was sunny and cloudless. It was hot. I began to look upwards at the Lakura mountain. Suddenly something flashed brightly in the sky and the thunder crashed. I got frightened and fell down. Now I looked and saw the wind felling the trees and the fire scorching the dry wood on the ground. I heard a noise somewhere. Now I jumped to my feet and saw two elks with their calf and two deer run to the Katanga. I got a fright and went back to my *chum*. At this moment the *Uchir* swooped, took the *elliun* and threw it to the river. Only the *diukcha* remained. Near it there were sitting on a leveled tree my father, my wife, and the children.

* The Evenks call thunder "*agdy*," whereas the Angara inhabitants call thunder "*grom*," as in Russian. So it was a blow of thunder, literally a blow. – *The Author.*

"We are looking at that direction where the sun sleeps in the winter (that is, at the north). Some miracle is occurring there; somebody is knocking again. In the direction of the Kimchu river one can see large smoke, the taiga is burning, strong heat is felt from there. And suddenly, somewhere far away, at the Chunku-kan river, a strong thunder crashed again and smoke appeared there.

"[Later] I went to look over that location, from which the wild animals were escaping and the heat was coming. There I saw a terrible miracle. The whole taiga has leveled, many trees on the ground were burning, dry grass and dry twigs were burning too, all the leaves in the forest got dry. It was very hot with much smoke. The smoke stung the eyes. It was completely impossible to look around. I was scared to death and ran back to the Chamba, to our *chum*. When I told my father about all this, he got a fright and died. The same day, we buried him according to our Tungus belief."

Many other Evenks, who participated in the *Munniak*, told something like the following: "The *agdy* birds struck many times, strongly struck. The *agdyllian** knocked, the Angara thunder struck blows, the *tanga* struck five blows. *Paktyrun* – as if shot. It was, however, *Uchir* that was burning the forest and leveling the trees. It took away Akulina's *elliun* and threw the *elliun* from Ulkigo's *chum* to the river. *Odyn*** was leveling the *diukcha*, it spoilt Akulina's squirrels. It was ruining, burning, leveling *labazes*. The *agdys* were ruining deer, dogs, and some men – three people have died: Lurbuman, Ivan Machakugyr, Luchetkan's brother, has hurt his arm and died, Uyban the shaman has become *bucho* and died on the Lakura."

Some personal statements were then made as well.

Andrey Onkoul: "I was looking for deer between the Lakura river and the Kimchu river. There I saw a pit and a dry river running from it. This is on Lakura mountain. Before the 'sorrow' there was no pit at this place, neither the 'dry river' (furrow)."

Molok Kurkagyr: "Half a day of *niulgui* (that is, a half of a day's march in summer on pack deer) from the Chunku-kan river to midday (that is, to the south) the taiga was also leveled completely; a great pit was made. The trees were there lying, their tops towards Erbogachen. Earlier, before the 'sorrow' there was no pit there; the forest was so dense, with a lot of squirrels."

Luchetkan: "On the mountain, on the Lakura range, near that place from which the Markitta stream and then the Markitta river are flowing, Akulina also saw a 'dry river' (furrow). At the end of this river there was a big pit filled up with soil. There were many leveled trees there."

Such were the main testimonies obtained from the Evenk witnesses, and some of who experienced the terror of the catastrophe of 1908.

The data collected were partly given in my article published in *Mirovedeniye* journal, 1927, No. 1. But before its publication, the text of the article was sent to L. A. Kulik who used it, together with the articles by S. V. Obruchev and A. V. Voznesensky, to prepare his first expedition.

In 1926 and somewhat later, both L. A. Kulik and I analyzed more than once the eyewitnesses' reports about "several claps of thunder" and "flashes that occurred somewhere high," admitting that the meteorite could probably explode in the atmosphere and several lumps could fall down. L. A. Kulik was so sure his hypothesis was correct that in 1927 he mistook the small circular lakes located at the Great marsh (so named by L. A. Kulik) inside the cirque Merrill, for craters formed by large meteorite fragments. It was only in the 1930s that he agreed that both the unevenness of the marshes inside the cirque Merrill and these "craters" were due to usual thermokarst processes, typical for the subarctic zone of permafrost.

Probably, because of this, the reports of the witnesses about several explosions do not attract any longer the attention of the Tunguska researchers.

At present, when a large team of researchers is examining the problem of the Tunguska catastrophe of 1908 in great depth, it seems to me rather interesting to publish a more detailed exposition of eyewitnesses reports than had been done in the article of 1927.

* Thunder. – *The Author*.

** *Odyn* – storm, squall – is represented in the Evenk demonology as a hydra-headed monster with enormous mouths and without any eyes or tail.

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